THE TERMINAL BOULDER BELT IN SHAWNEE COUNTY.

By B. B. SMYTH, Topeka.

Stretching across the southern part of Shawnee county there occurs a line of red rocks, more or less rounded by the action of water and abrasion. This line is very noticeable, because the rocks in it are unusually hard and of a different color from all other rocks that are found *in situ*, and lie loosely upon the surface in such a way as to give the impression that they were thrown there and had subsequently sunken slightly into the earth.

This line is a part of a line stretching across the United States for a distance of more than 2,000 miles; reaching from the British line in northwestern Montana, entirely across the states of Montana, North and South Dakota, and Nebraska, one corner of Kansas, across the states of Missouri, Illinois, Indiana, Ohio, Pennsylvania, and New Jersey. It continues eastward from end to end over Long Island, and still continues eastward over the bottom of the shallow ocean south of Rhode Island and Massachusetts.

This line is not, however, in Shawnee county, at least, a moraine in truth; it is a distinct and well-defined border belt of boulders, with slight morainic tendencies. The boulders in this line are from one to ten feet in diameter, and from close together to thirty or forty feet apart. Four of the largest in the line are six or seven feet high and ten feet across. These are about seven miles apart, one in a place. Three of them are within ten feet of the very front; a fourth is a little further back. One of them, six feet high and ten feet across is split vertically into three parts; the parts have sunken into the ground somewhat, and are separated from each other far enough to permit a cow to pass through. The interior parts are well covered with lichens of very slow growth. A fifth, about 600 feet back of the line, is three feet high and twelve by eight feet across. It stands in ground that is sometimes springy and soft, and probably rests on the bed-rock, which is two feet below the surface. Several others, somewhat larger, stand on the high ground north of the Kaw, and about twelve miles back from the moraine. One, about the same distance further back, is said by Professor Hay, who has seen it, to be twenty-seven feet across. These are all in Shawnee county.

The boulders are mostly on hilltops and southern exposures. There seem to be all varieties of granitoid, gneissoid, quartzose, and schistose rocks, conglomerates, and metamorphic sandstones. They are red, pink, purple, gray, green, black, and striped with pink and yellow; but red is the predominating color. They are usually very hard, especially those exposed; sometimes one that is covered is decomposed, like these samples (Nos. 1 and 2) in my hand.

COURSE OF THE MORAINE.

This train of boulders traverses the county from east to west, as indicated on the map, commencing near the southeast corner, about two miles north of Richland. It follows the southern crest of the bluffs north of the Wakarusa, until Linn creek is reached, which it crosses, passing up tne creek to Berryton, continues the same course to Pauline, and on to the westward three miles. Here it makes a sharp turn to the north for two miles until the banks of the Shunganunga are reached; it then disappears.

A recent attempt to trace the continuance of this boulder train, in company with Dr. Wm. Smith, of Topeka, resulted in finding it to make a sharp detour

around to the southwest, in the bottom of the Shunganunga valley. It reappears south of the Shunganunga, at a point two miles southwest from its disappearance. Over that portion of its course the train of boulders, with a large amount of accompanying drift, rests on the naked bed-rock at the bottom of the Shunganunga valley. Its thickness here, wherever it could be seen, by reason of the creek cutting through it, is from four to sixteen feet. It is covered with ten to twenty feet of native prairie earth washin in from the surrounding high lands. The drift debris at the bottom of the valley has considerable clay and small pebbles of various soft rocks, a feature not observable on the surface. Here is an excellent opportunity for studying the character of the original deposit, where it has been buried since its deposit and left undisturbed to the present day. The upper portion of this buried deposit gradually changes in its character to that of native prairie earth, showing that the drift material and the earth from the prairies were being washed down together, at first the former predominating, as the headwaters of the creek are either on the line of the moraine or entirely within the glaciated district; and later the prairie earth predominating, finally being alone, as the drift material became gradually covered up, and was being washed no more.

Thus there is a bay or sinus opening to the southwest, about two miles deep and two miles wide. Within this embayment stands Burnett's mound, a hill half a mile wide and two miles long, and about 150 feet high, projecting northward from some high lands to the south. Except on the northwest side of the mound, where the moraine approaches to a distance of about one-third of a mile, there is not a sign of any glacial material within half a mile of the hill. North of the line indicated, all over the county, there are to be found on the high lands boulders in plenty, and hidden in occasional hollows beds of drift material that have not yet been washed away. South of that line there is not a particle of boulder clay and not a boulder, save here and there one whose presence there can readily be accounted for. This is also true within that bay; but here there is no exception. There is yet to be found the first sign of glacial material within the bay.

On the east side of the mound the two miles of the boulder train run along the crest of a native ridge parallel with the hill, with a slight valley intervening. On the north and west sides of the mound the moraine is covered up in the Shunganunga valley, as stated. This, Prof. T. C. Chamberlin, of the University of Chicago, says, in the Journal of Geology for November-December, 1894, "affords a criterion of age that is new, so far as we know."

This conclusion is irresistible: That on the east side, and partly on the other sides, the reflection of the sun's rays from the hill kept the ice from approaching closer; and on the northwest side, where the reflected rays would be the least powerful, the torrent of the Shunganunga creek, passing around the north end of the mound, heavily washed the base of the ice, and aided the sun's rays in keeping the ice from approaching closer.* From the place where the moraine reappears above ground south of the Shunganunga, it continues its general course of north 67 degrees west across the county with very little deviation. Valleys crossing its course do not seem to affect it. It crosses hills and valleys in a straight line, except that in the Mission creek valley the moraine is advanced two miles, making a lobe two miles deep and several miles wide.

*Later studies of the region show that a swift-flowing river, half a mile wide, passed around the mound and flowed southward into the Wakarusa, effectually preventing the ice from reaching the mound, and having more influence in that direction than the sun's rays.

HEIGHT OF THE ICE.

This ought to give some clew to the height of the ice at its front. Another clew is obtained in Martin's Hill, west of Topeka, the hill west of the sugar mill, and the hill at Valencia, all overlooking the Kaw, and none of them covered by the ice, but standing as islands surrounded by fields of ice, since the ice that passed up the valley on either side spread out and met a short distance south of these hills. In Kansas, too, some idea may be had of the total height of the ice in this way: The front of the ice in this state was the arc of a circle, as shown by that terminal boulder train. The focus of the arc is a little above White Cloud, Doniphan county. The main glacier came straight down the Missouri valley, or a little east of it, and spread out to the south and westward like the radiating lines of an hepatic or the venation of a maidenhair fern. It must also have spread to the southeastward, until held in check by vast fields of ice in that direction.

A field of ice that failed to touch Burnett's mound, though it passed two miles further south on either side, could not have much exceeded the height of the mound, say 150 feet. At Martin's hill the ice could not have exceeded 400 feet in height, else it could easily have passed over the hill; since it passed over lands of equal height wherever the northern slopes were more gentle. If we assume, then, that the height at Martin's hill, six miles north from the ice front, was 400 feet, and allow an average of 40 feet to the mile as the slope of the surface of the ice, it will indicate 3,000 feet as the height of the ice at White Cloud. The elevation of the uplands at White Cloud is 1,000 feet above sea level, the same as at Topeka. The elevation of the highest intervening lands is 1,150 feet.

SOURCE OF THE ROCKS.

It has always been a question where these rocks could have come from. We find no rocks just like them in any of the states mentioned. Hence they are not local rocks. Similar rocks are to be found *in situ* in Keewatin, north of Lake Winnipeg, in eastern Manitoba, northeastern Minnesota, and in Ontario, north and east of Lake Superior, along what is known as the Laurentian range of mountains.

These stones, Prof. Ulysses S. Grant, of Minneapolis, writes me, are found *in situ* nearly all over Minnesota. They are not found this side of Minnesota, except these (Nos. 17 to 22, and 24), which are found in the Sioux quartzite, in the valley of the Big Sioux and farther east. This specimen (No. 20) contains evidence of glaciation in itself. Look at these pebbles. Waterworn, are they not? They are worn exactly the same as similar pebbles are worn by ice and water at the present day. Yet immeasurable ages have passed over this earth since the formation of these pebbles. Here is a specimen (No. 24) from the same formation that contains evidences of water and no ice. How do you account for those beautiful lines except on the hypothesis that these particles were laid in water in which the currents were regularly reversed, intermittent, or otherwise changed? This specimen (No. 23), a red jasper, Professor Grant says, "is known to form pebbles in the base of the Sioux quartzite, near New Ulm, Minnesota." He says further: "This is the most probable source for your specimen. Exactly similar rocks are found in the iron ranges on both sides of Lake Superior."

How came these rocks in our boulder train so far from their native home? The question as to whether they were washed there by ocean waves would be at once decided in the negative. The question as to whether they were transported by icebergs across seas of open water has been considered; and

the question as to whether they were transported by glaciers coming from the north has received serious consideration. The iceberg question must be decided in the negative, because icebergs scatter and deposit their loads everywhere over their courses in warmer seas. These stones, on the contrary, are scattered in a very definite line, a line which is continuous in all its course of more than 2,000 miles, except where it can be shown to be broken through local causes.

CAUSES OF THE ICE PERIOD.

Whether these stones have been carried by ice from the north, over dry land, raises the question as to what the climate must have been in past ages to cause such a degree of cold as to allow glaciers to accumulate to an extent sufficient to reach as far southward as Kansas and southern Illinois.

The question of change of position of the poles and consequent change of all latitudes on the earth is too absurd to merit serious consideration. That there is a very small change going on I will not deny. But the oblateness and fixity of the earth will preclude the possibility of a change of latitude at any place sufficient to affect the climate.

The question of land elevation as a cause of the glacial epoch has received serious consideration and some believers. But the arguments are specious; they are based on false premises. Elevation and depression of the northern hemisphere is a regular result of the earth's astronomical changes, not a cause. If elevation were a cause, the greatest extent of ice should be looked for in the highest regions. But the greatest extent of ice occurred in the low lands of Illinois and Indiana, while the elevated regions of the northern peninsula of Michigan and of Cattaraugus county, New York, proved an effectual barrier to the passage of the ice over them; and the elevated region of the "great plains" had free running streams every summer, while Iowa, north Missouri, and all the low plain region east to western Pennsylvania was covered with ice for a thousand years.

If glaciation of the northern hemisphere is not brought about by terrestrial causes, it is well to consider the astronomical changes that could tend to bring about such a result:

First. Ellipticity of the earth's orbit and precession of the equinoxes. If the earth's orbit were a true circle, the summer and winter would be equal in length. As it is, the six months of summer is now six days longer than the six months of winter. The perihelion point of the earth is reached about the first of January. This point recedes in the orbit a little, so that the earth reaches it 50 seconds of space earlier each year, and makes the complete round of the earth's orbit in 25,868 years. This is called a platonic year. Progression of the perihelion point of the earth's orbit (11 seconds per year) is added to this, making 61 seconds of space each year and reducing the platonic year to 21,408 years.

The heat at present received in the northern hemisphere in summer, compared with that received in winter is as 176 to 100. In 13,000 years more, when the earth reaches its perihelion on the 4th of July, and the platonic winter comes to the northern hemisphere, the amount of heat received in the summer season as compared with that received during the winter season will be as 160 to 100. Thus, comparing 176 with 160 the northern hemisphere receives 10 per cent. less heat each summer during the platonic winter than during the present summers. This 10 per cent. distributed over the northern hemisphere would vary from nothing at the equator to 10 per cent. in the latitude of Kansas and 23 per cent. around the north pole. Ten per cent. of re-

duction of summer temperature in Kansas would reduce the summer temperature from 78 degrees to 73 degrees, and the annual mean temperature from 55 degrees to 53 degrees. A reduction of 23 per cent. around the north pole would move the isothermal line of 32 degrees annual mean temperature 10 degrees to the south, as its heat is about all received in the six months of summer; and, inasmuch as the reduction would be greater over the land than over the ocean, we might safely look for the limit of permanent ice to be removed to the south of James bay, and even to approach Lake Superior. However, this cause would be insufficient to bring permanent ice into Minnesota. But it would become an important factor in aid of other causes.

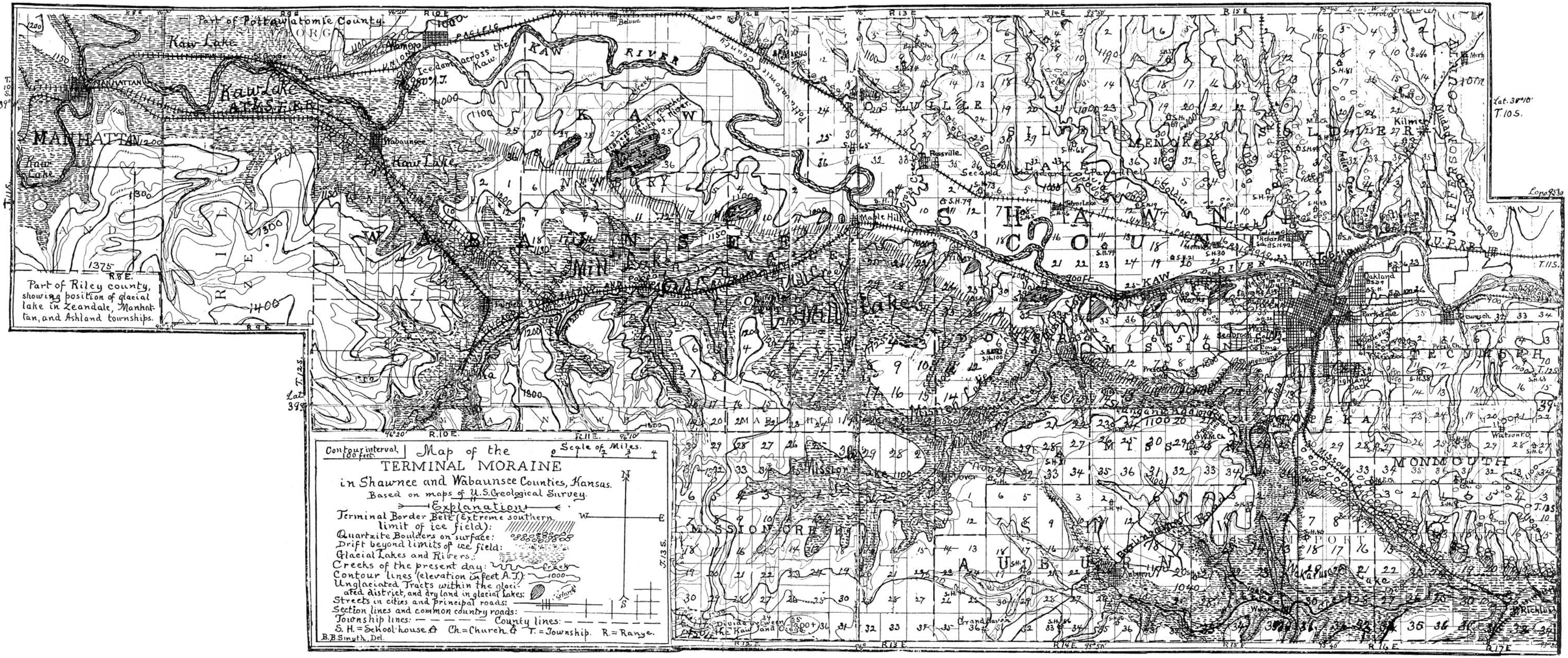
Second. Variation of ellipticity of the earth's orbit. It has been calculated that the ellipticity of the earth 100,000 years ago was two and one-half times what it is now. If that were true, the difference between summer and winter would be 15 days instead of six days; and the amount of heat received by the northern hemisphere each summer during the platonic winter would be 25 per cent. less instead of 10 per cent. less, as at present. This at the north pole would be 58 per cent. less than the amount of heat received there during the summer season at the present time. This is a very important amount, and might or might not be sufficient to push the ice from British America down into Minnesota.

These two variations, having different periodic times, would sometimes neutralize each other to some extent, and at other times reinforce each other. It may be possible to calculate the effects at each particular period; but I have not the data necessary to attempt it.

But there is a third astronomical cause more important than either of the others, namely: Changes of obliquity of the earth's axis. It has been calculated by Laplace that the variation in obliquity amounts to 1 degree 33 minutes 45 seconds. Drayson, of England, as clearly shown by Gen. J. C. Cowell (see Science, December 22, 1893), has demonstrated that the change of obliquity of the earth's axis is caused, not by a nutation of the earth's axis, but by a revolution of the pole of the heavens around a point six degrees removed from the pole of the ecliptic. This, if true, is a very important point. It would cause the obliquity of the earth's axis (since that always points to the pole of the ecliptic) to vary from 23 degrees 25 minutes 47 seconds to 35 degrees 25 minutes 47 seconds. The length of this period is said to be 31,682 years. The time of least obliquity is placed at 400 years hence, and the period of greatest obliquity is placed 13,544 years ago. Thirty-five degrees obliquity would carry the tropic of Cancer up into Oklahoma, Arkansas, and Tennessee; and bring the arctic circle down into Saskatchewan and south of Hudson bay. This cause would be amply sufficient to account for all the glacial epochs that have ever existed on the earth; and they seem to have existed in varying degrees for all past time, even down to the Huronian.

INFLUENCE OF THE OCEANS.

Another thing to be considered in connection with this is the form of the oceans. It is well known that great currents of warm water are flowing northward through the Atlantic ocean near the Atlantic coast, and through the Pacific near the Asiatic coast. After the lapse of a long period of time, when the increasing cold of the platonic winter causes the ice of the Arctic ocean to spread so as to cover a large part of the northen Atlantic ocean and close Bering strait, the warmer currents are entirely shut off from reaching the polar seas, and there is nothing to prevent an increased accumulation of the ice around the pole. The ice naturally spreads farthest in



Map of the
TERMINAL MORAINE
in Shawnee and Wabaunsee Counties, Kansas.
Based on maps of U.S. Geological Survey.
Contour interval, 100 feet.
Scale of Miles.
0 1 2 3 4
Explanation.
Terminal Border Belt (Extreme southern limit of ice field):
Quartzite Boulders on surface:
Drift beyond limits of ice field:
Glacial Lakes and Rivers:
Creeks of the present day:
Contour lines (elevation in feet A.T.):
Unglaciated Tracts within the glaciated district, and dry land in glacial lakes:
Streets in cities and principal roads:
Section lines and common country roads:
Township lines: County lines:
S. H. = School-house Ch. = Church T. = Township R. = Range.
B.B. Smyth, Del.
Part of Riley county, showing position of glacial lake in Zeandale, Manhattan, and Ashland townships.
Part of Pottawatomie County
Kaw Lake
MANHATTAN
Wabaunsee
KAW RIVER
Ice dam across the Kaw
Mill Lake
Mission Lake
Rossville
Maple Hill
MISSION CREEK
AUBURN
TOPEKA
TECUMSEH
MONMOUTH
JEFFERSON COUNTY

the direction of least resistance, which is over the continents. The warm oceanic currents prevent the ice from reaching very far to the south in either ocean. But there is nothing to prevent the ice from reaching very far to the south in the region of Hudson bay and westward of that.

NECESSITIES OF AN ICE PERIOD.

Two features necessary to the accumulation of a large amount of ice are the contiguity of large bodies of water and an increase in the summer heat. These were obtained in the Gulf of Mexico, which in past times reached farther north than at the present day, and the short hot summers that occur during the platonic winter. Large quantities of water were raised from the Gulf of Mexico and carried northward by the south winds until the ice was reached, where it became quickly converted into snow or rain. Then, too, the melting of the ice in the summer season furnished plenty of water close to the ice; so that a three-day blow from the south could carry much moisture far to the north.

The north winds blowing over the ice fields had a temperature far below freezing; and, supposing that changes in direction of wind occur as they do at the present day, they would present this feature: A very warm south wind heavily laden with moisture, met by a very cold north wind, causing precipitation of a large amount of moisture in the form of heavy snows in the region of Hudson bay, and heavy rainfall on the plains south. Thus the snow accumulated and was piled up higher and higher. This snow, by reason of its great height and pressure, became packed solidly into ice and did as glaciers always do, pushed its foot away from the region of greatest accumulation toward the warmer regions. Hence it was pushed to the south until the melting power of the sun exceeded the rate of travel of the ice.

RATE OF TRANSIT.

As to the length of time required to bring these rocks here. It is by no means necessary to consider that they should be brought from Ontario to Kansas during a single epoch. These stones, you will observe, are a very enduring kind. Indeed they seem even to become harder by exposure to our southern sun; and, as Doctor Smith and I noticed in examining them, they are mostly polished on the southwest side, apparently by attrition of the dust particles raised during the few dust storms that we have. It is a higher polish than is received by abrasion during transit. If they have been here long enough to become so highly polished by so infinitesimal a cause, they have been here long enough for all accompanying softer rocks, except in the buried portions of the moraine, to have become entirely disintegrated and carried away. Indeed, they have been here long enough for some of these granitoid rocks to have become decomposed since their arrival, as is shown by this specimen which I dug up from the buried portion of the moraine, which, when I found it six weeks ago, was a shapely round boulder, but which broke to pieces by the pressure necessary to remove it from the earth, and which I now crumble in my fingers before yeu. It was a solid stone when it was deposited in the bottom of the Shunganunga; but became decomposed by the small amount of alkali or other deleterious material in the surrounding soil. Many a story of time, temperature, travels, and attending conditions is written in the bottom of that old Shunganunga, yet to be read by the intelligent glacial geologist.

How can we know where these stones were picked up by ice during the Kansan epoch from the place where they were deposited during the last pre-

ceding epoch? If the front of the ice during any epoch should advance farther than it did at the culmination of the last preceding epoch it would leave enough of these rocks accompanied by other debris to form a distinct moraine, possibly composed largely of rocks collected in the last few miles. Such moraine would lose its morainic character after the lapse of a sufficiently long time; and there would be nothing left but these hard rocks, ready to be moved forward if need be at the culmination of the next succeeding epoch. We may find out, approximately, perhaps, where any of these stones came from originally; but can we tell how many times they rested for 20,000 years, more or less, at a time, before they reached here?

At the ordinary rate of travel of ice in a glacier, this piece of jasper could easily have been moved from New Ulm, Minn., to Topeka, Kan., in a single epoch; but, as this piece is unconnected with any quartzite, and as Prof. U. S. Grant says that at New Ulm it forms pebbles in the base of the Sioux quartzite, but is found in mass on both sides of Lake Superior, it is more reasonable to suppose it came originally from north of Lake Superior, and that it reached here by stages.

TIME OF THE ICE EPOCH.

If the height of the last platonic winter occurred say 11,350 years ago, and the obliquity of the earth at that time was 30 degrees, it is easy to see that there would be no great trouble in the ice being pushed from Hudson bay down into southern Minnesota, even though the ellipticity of the earth's orbit were no greater than at present.

And whenever the greatest obliquity of the earth's axis coincided with the greatest ellipticity of the earth's orbit, and both coincided with the earth reaching its perihelion about the 4th of July, the greatest glacial epoch would take place; and this was when the ice was pushed to its utmost extension in Kansas, and was what Prof. T. C. Chamberlin calls in Geikie's Great Ice Age the "Kansan" epoch, to indicate and individualize the epoch during which the ice reached its greatest extent toward the south, and to individualize the deposit made during that epoch, as is clearly shown in this boulder train through Shawnee and other counties of Kansas. The number of platonic years that have passed since then has not yet been accurately calculated; neither has the number of ice periods, only approximately, and supposed to be five; which would place the Kansan epoch, as this is the middle of the platonic summer in the northern hemisphere, between 110,000 and 125,000 years ago.

Further study will be given this subject.